Principles and practical tips for scientific visualization

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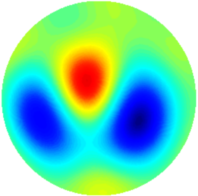

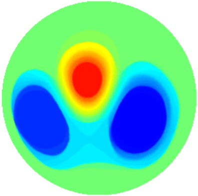

Finnish Centre of Excellence in Inverse Problems Research

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http://wiki.helsinki.fi/display/inverse/Home

This my industrial-academic background

1999: PhD, Helsinki University of Technology, Finland

2000: R&D scientist at Instrumentarium Imaging

2002: Postdoc at Gunma University, Japan

2004: R&D scientist at GE Healthcare

2005: R&D scientist at Palodex Group

2006: Professor, Tampere University of Technology, Finland

2009: Professor, University of Helsinki, Finland

Outline

Basic principles

1D example: plotting functions of one variable

1D example: convolution

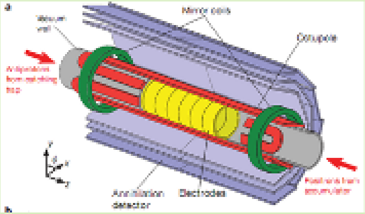
2D example: comparing images

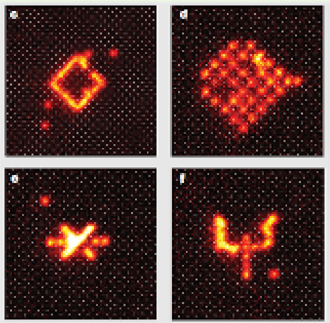
Case study: Electrical impedance tomography

Some basic principles of presenting scientific data in a visual form

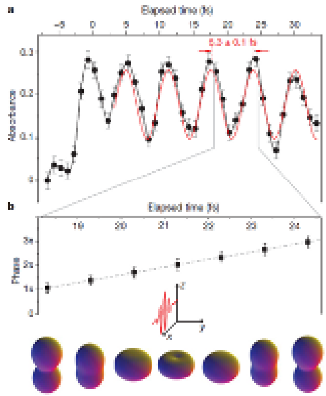
1. Make sure the audience can see what you want to show.
2. Examine every drop of color in your image. Does it carry relevant information? If not, consider removing it.
3. Use all of your available image space.
4. Show data instead of irrelevant structure.
5. Make comparisons easy and accurate.

What's So Interesting About AMO Physics?





Chad Orzel
Department of Physics
and Astronomy
Union College
Schenectady, NY



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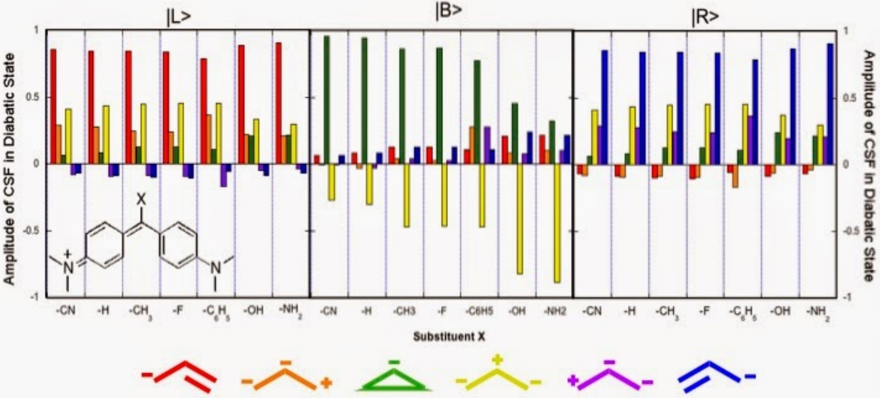
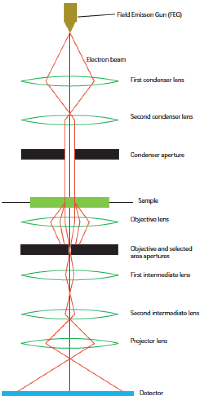
http://slideshare.net/orzelc

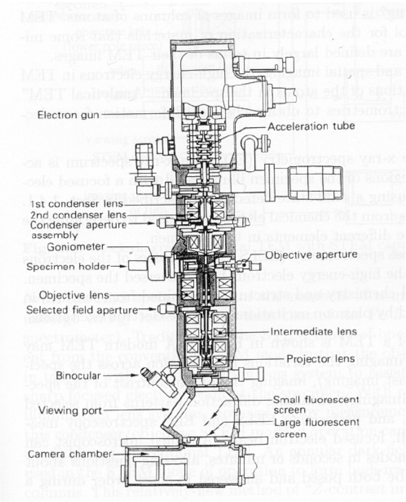
Diabatic States are Similar



Diabatic states highlight consistent changes across dye series; Structure is Identifiable With 3-State Hamiltonian Model

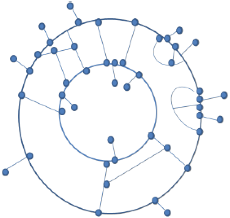
The transmission electron microscope (TEM)



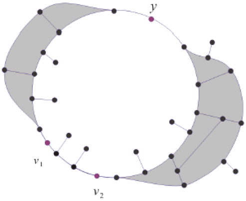


Decomposing Cubic Graphs

Case 1: $\partial_1 \cap \partial_2 = \emptyset$



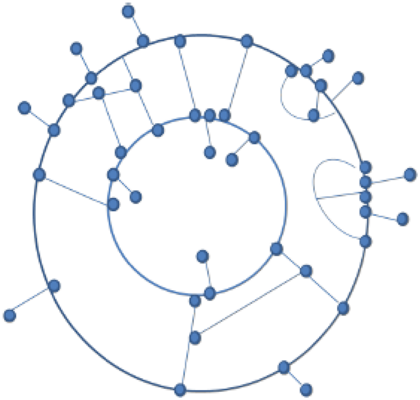
Case 2: $\partial_1 \cap \partial_2 \neq \emptyset$

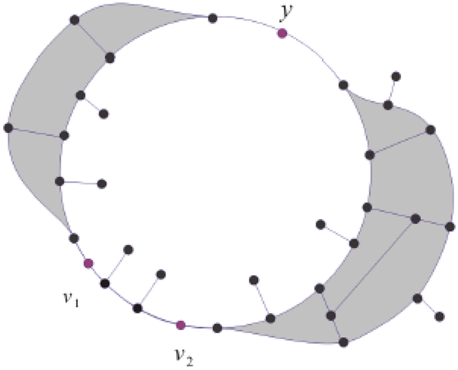


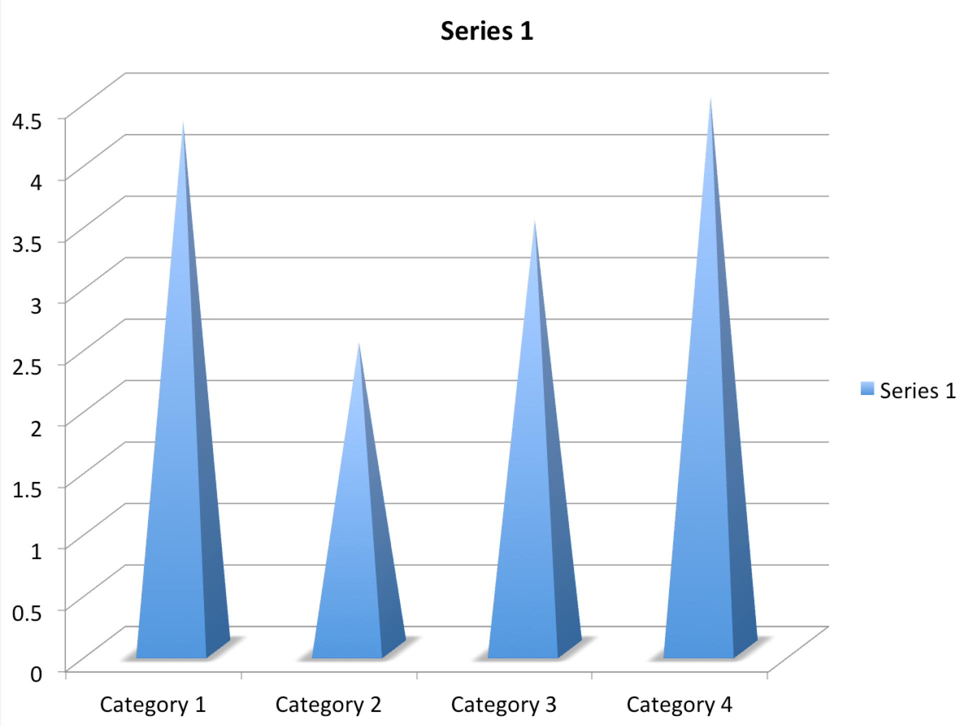
Decomposing Cubic Graphs

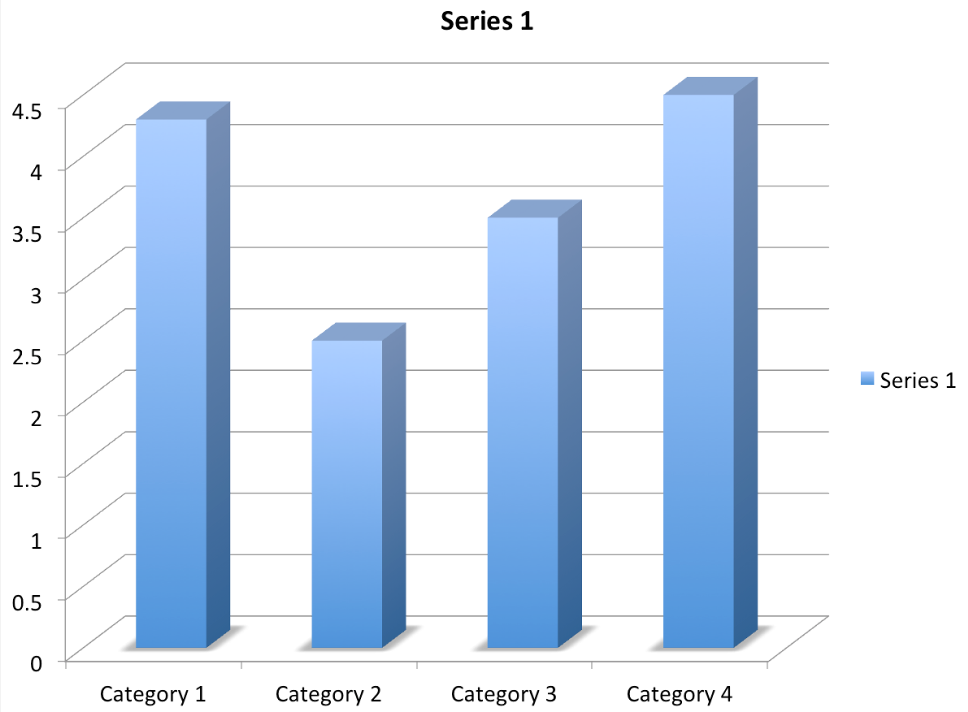
Case 1: $\partial_1 \cap \partial_2 = \emptyset$

Case 2: $\partial_1 \cap \partial_2 \neq \emptyset$






Series 1
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Category 1
Category 2
Category 3
Category 4
Series 1


Series 1
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2.5
2
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1
0.5
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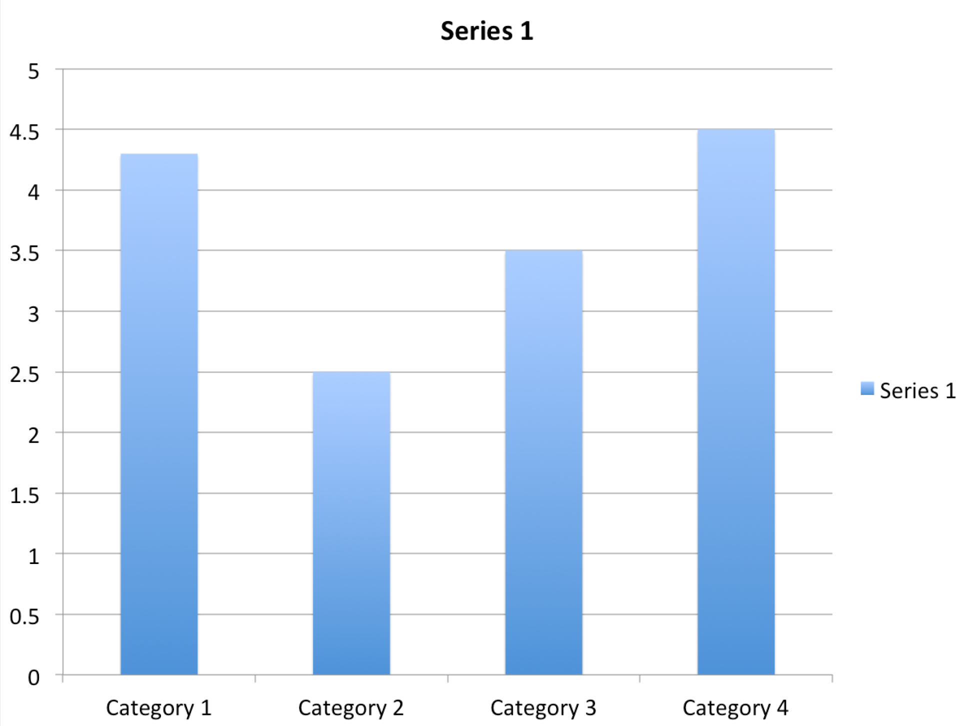
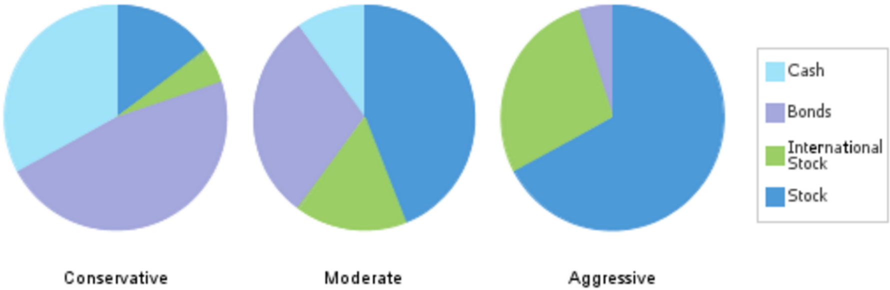
Category 1
Category 2
Category 3
Category 4
Series 1



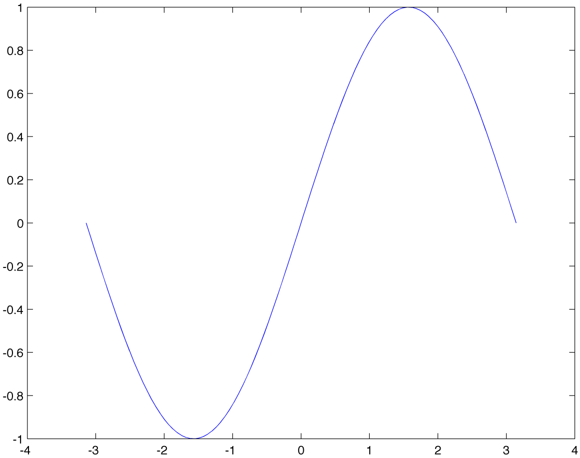
Series 1
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Category 1
Category 2
Category 3
Category 4
Series 1

Precision tip: never use multiple pie charts

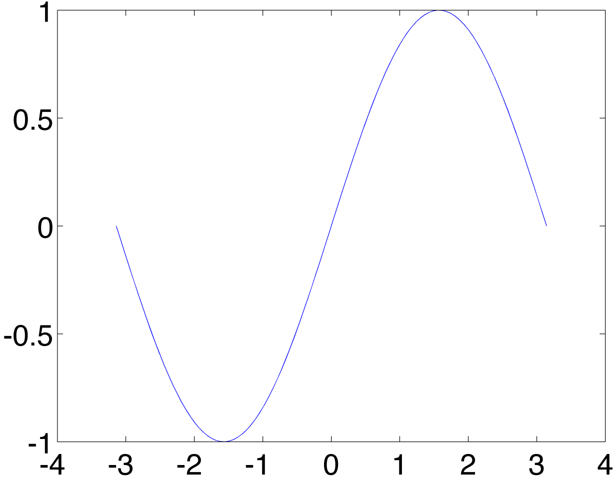


Outline

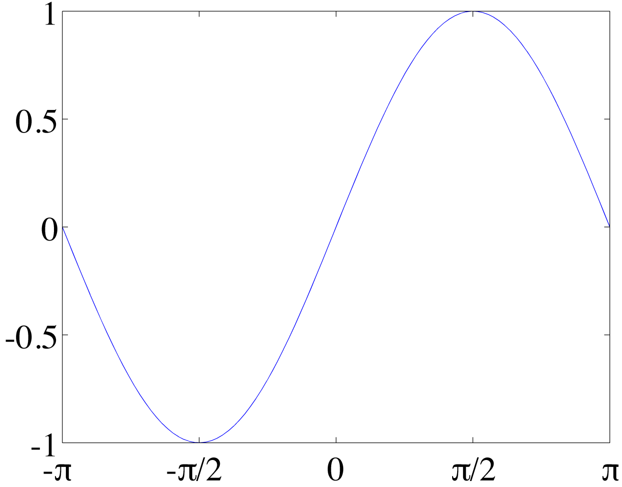
Here you see the sine function, plotted in the interval $[-\pi, \pi]$ using Matlab's default settings



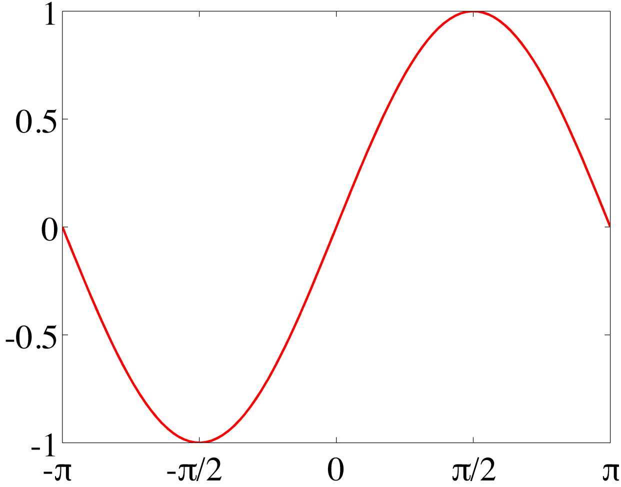
Let's make the numbers larger so you can see them properly



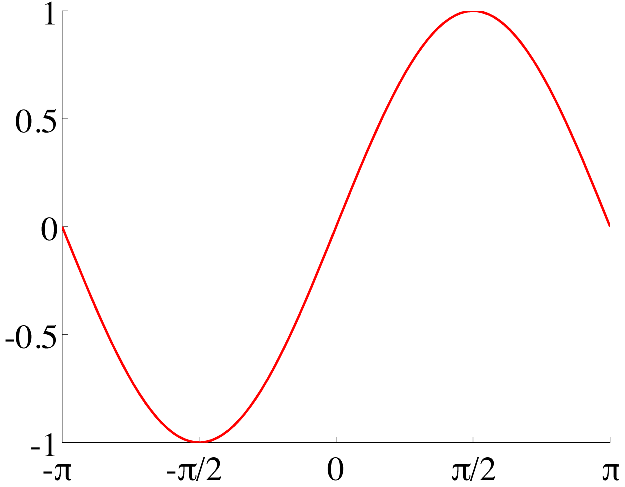
Actually, we could show tickmarks that are more relevant for this particular function



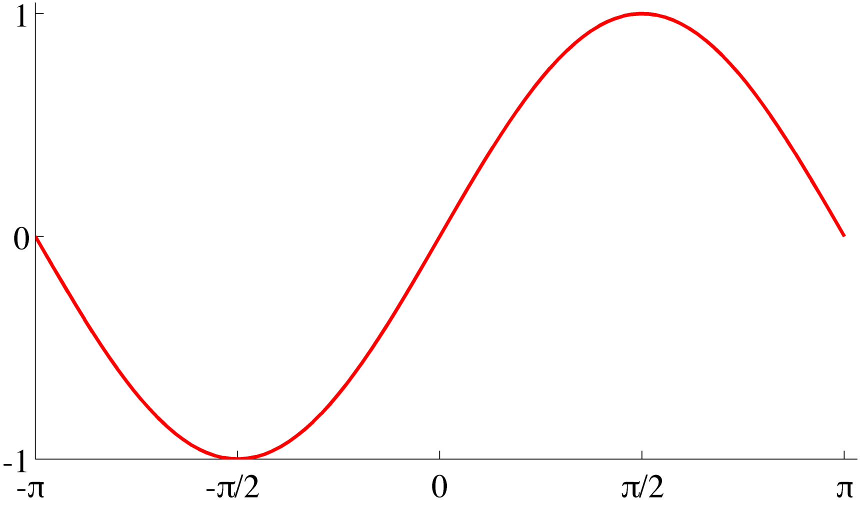
Here we emphasize the data (sine function) over the surrounding structure



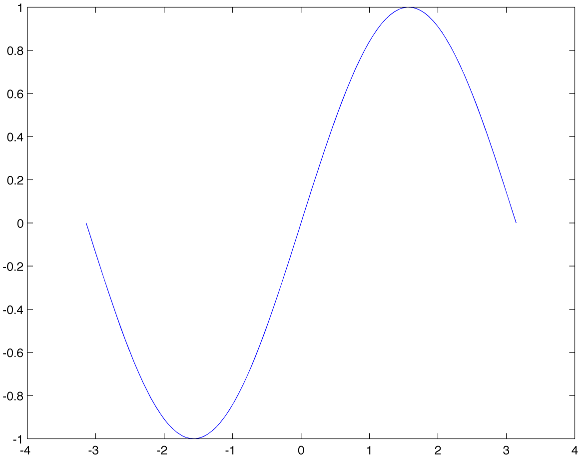
The box around the plot is not carrying relevant information, so we remove it



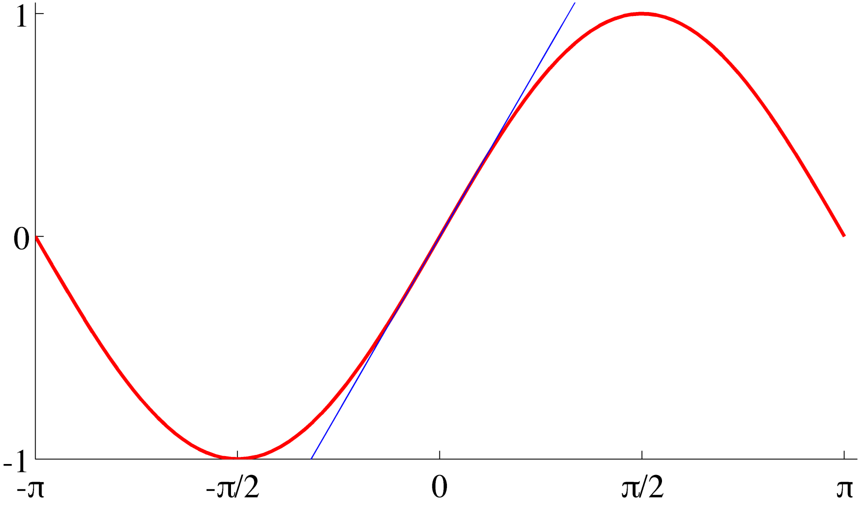
Finally, we use all available space we have on this presentation slide



Compare to the original plot where we used Matlab's default settings

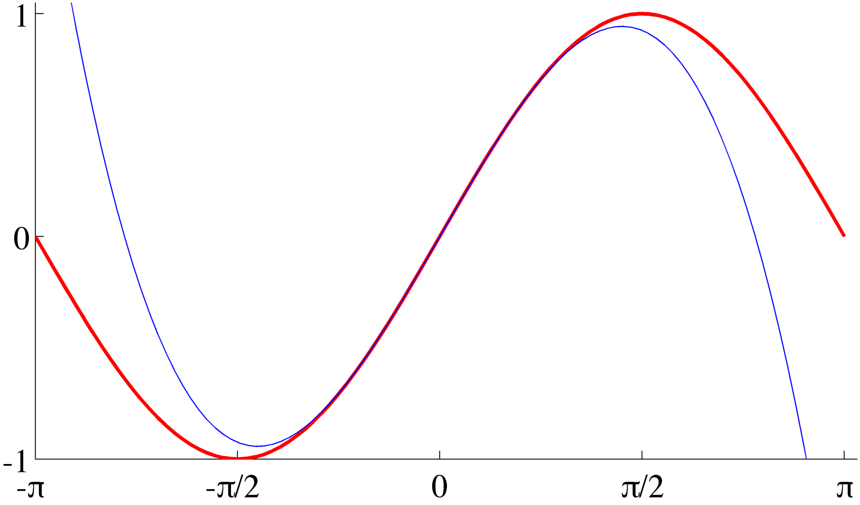


No we can consider adding more functions, such as the first-order Taylor series around zero



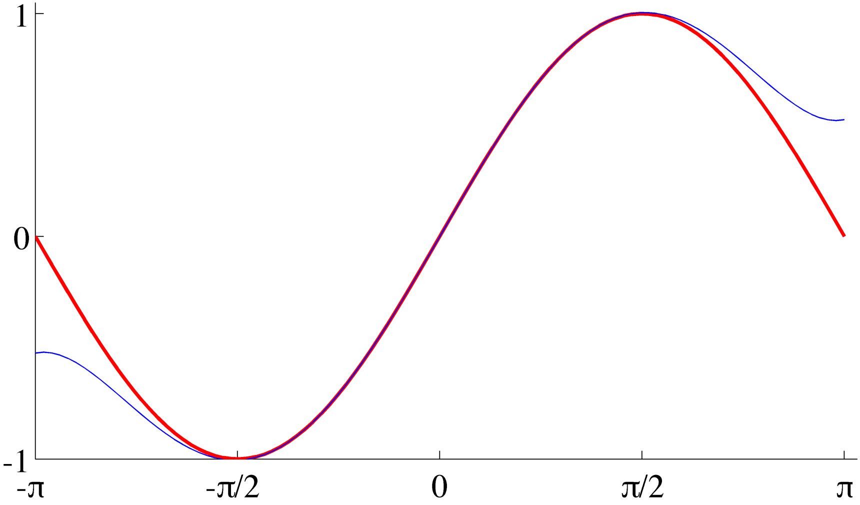
Here is the third-order approximation

$\sin x \approx x - x^3/6$

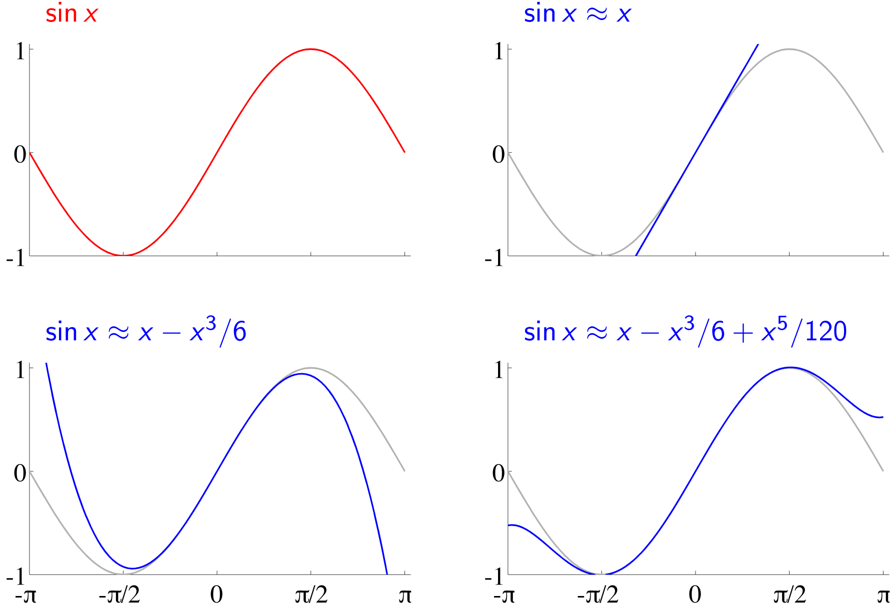


Here is the fifth-order approximation

$\sin x \approx x - x^3/6 + x^5/120$



Here is a small-multiple approach



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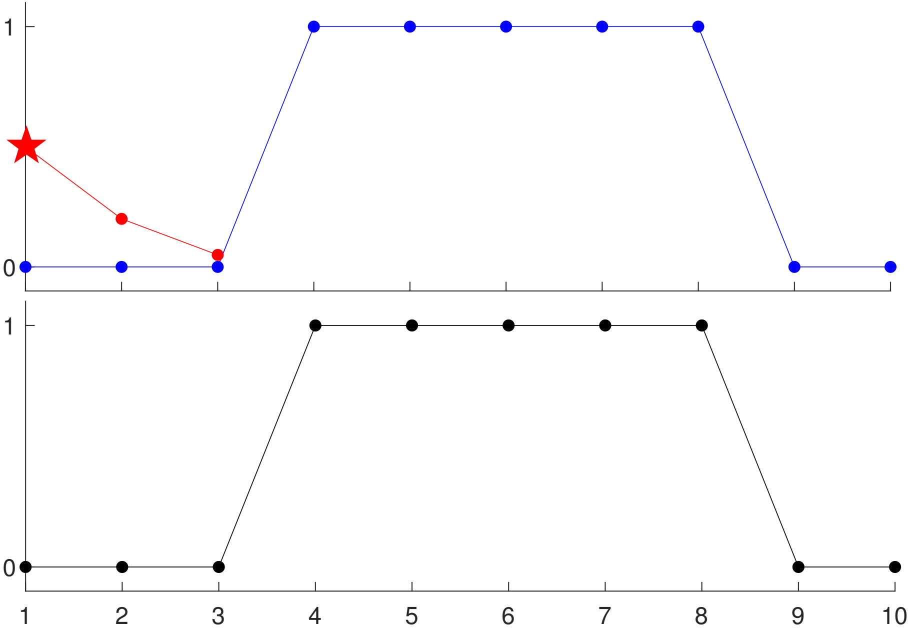
1D example: plotting functions of one variable

1D example: convolution

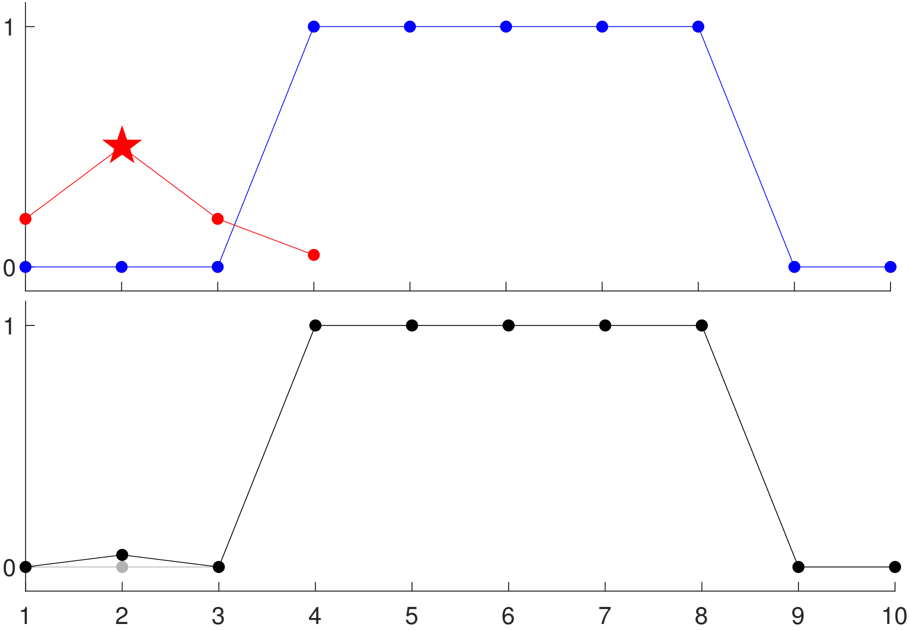
2D example: comparing images

Case study: Electrical impedance tomography

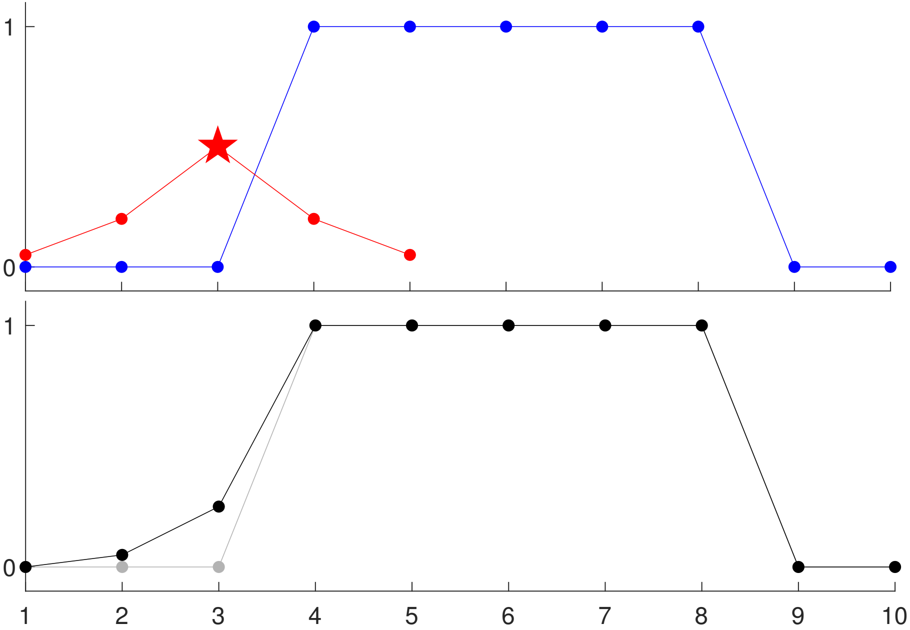
Konvoluutio, sijainti 1



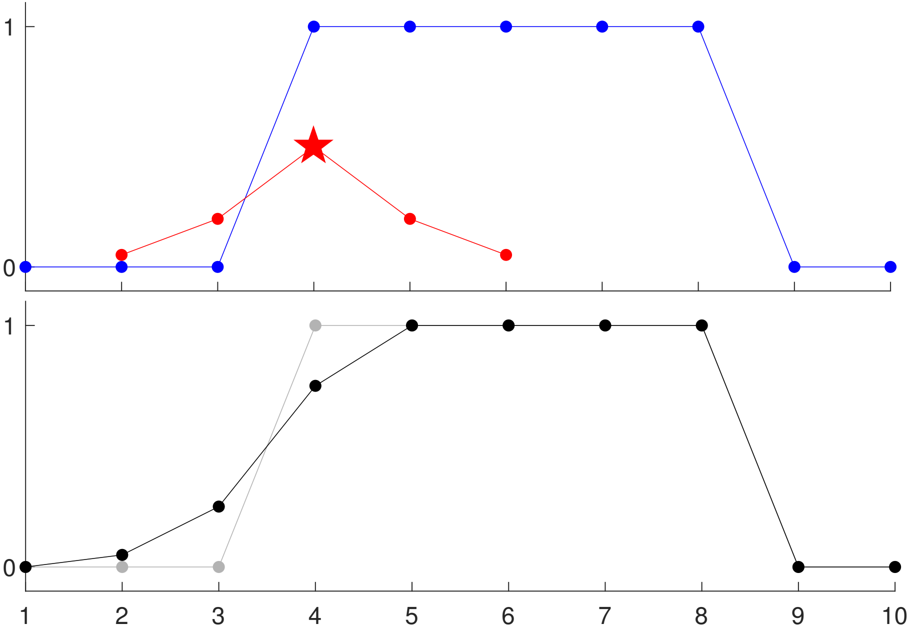
Konvoluutio, sijainti 2



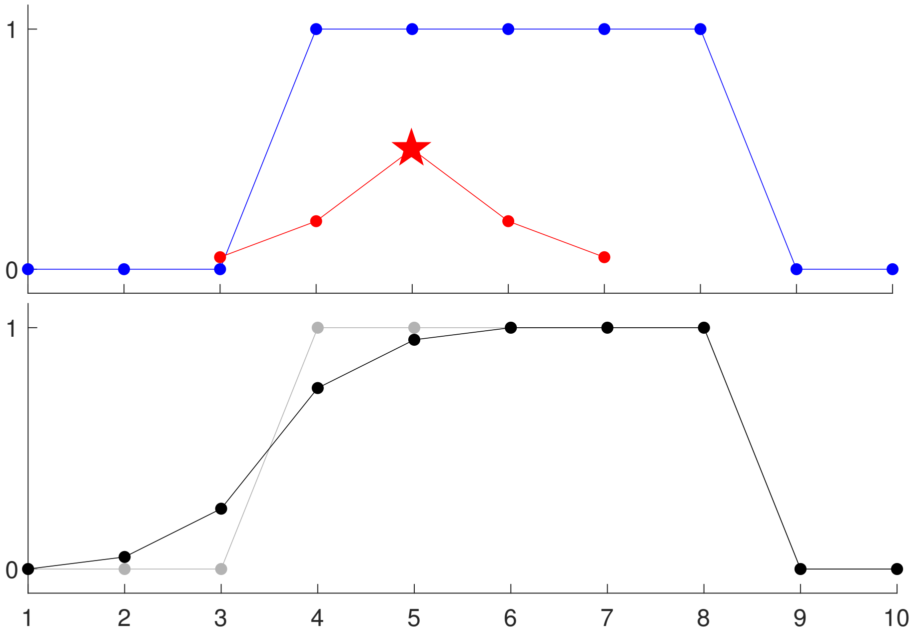
Konvoluutio, sijainti 3



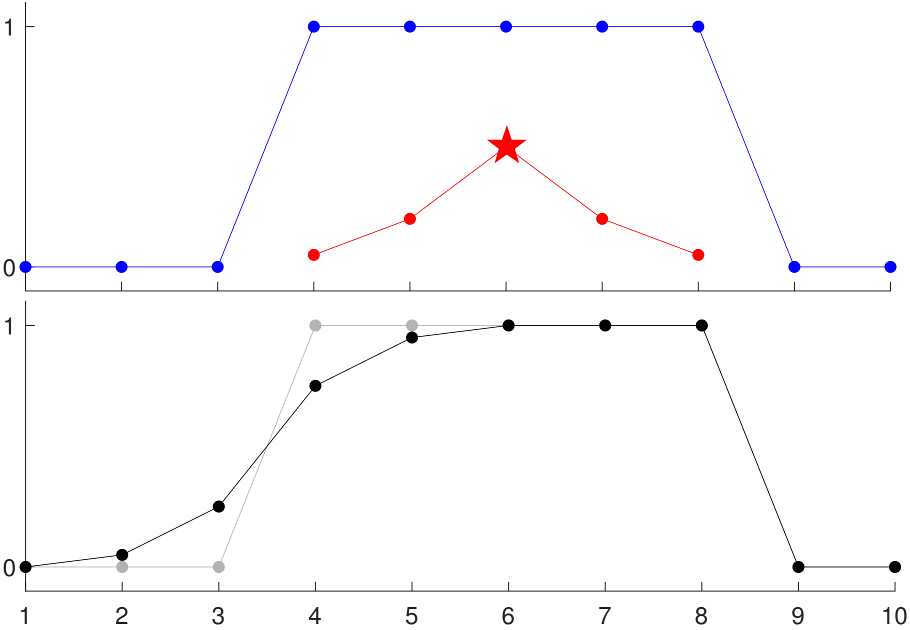
Konvoluutio, sijainti 4



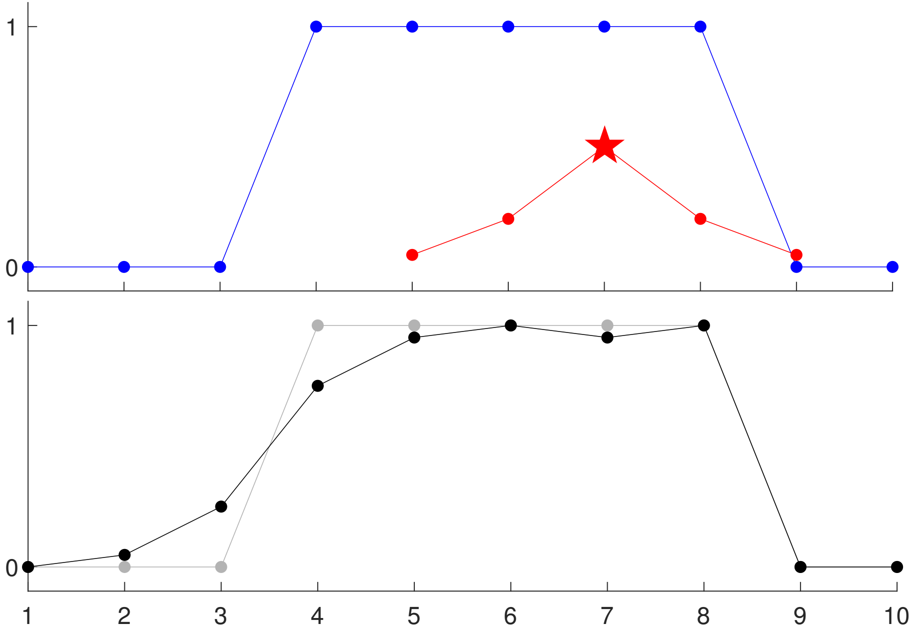
Konvoluutio, sijainti 5



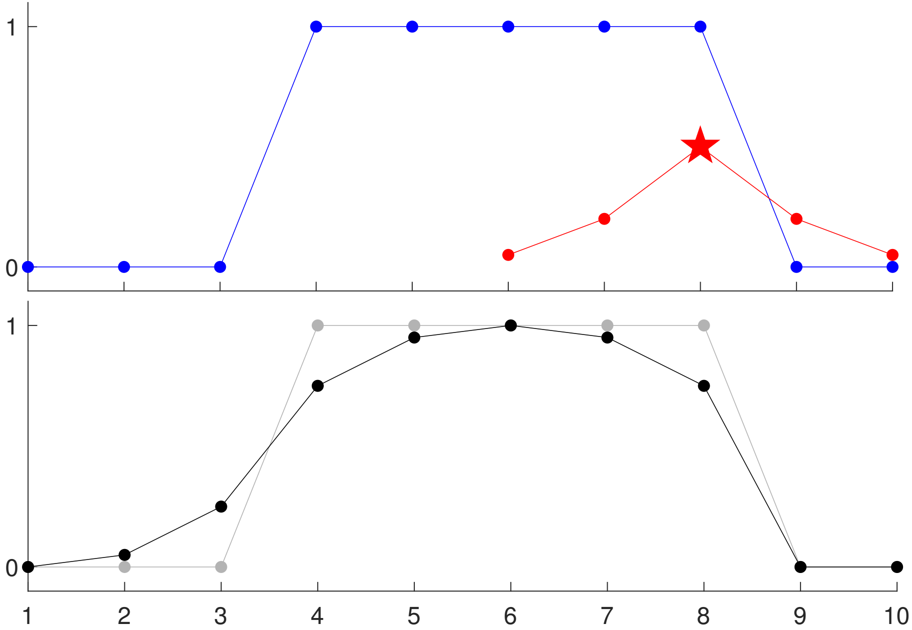
Konvoluutio, sijainti 6



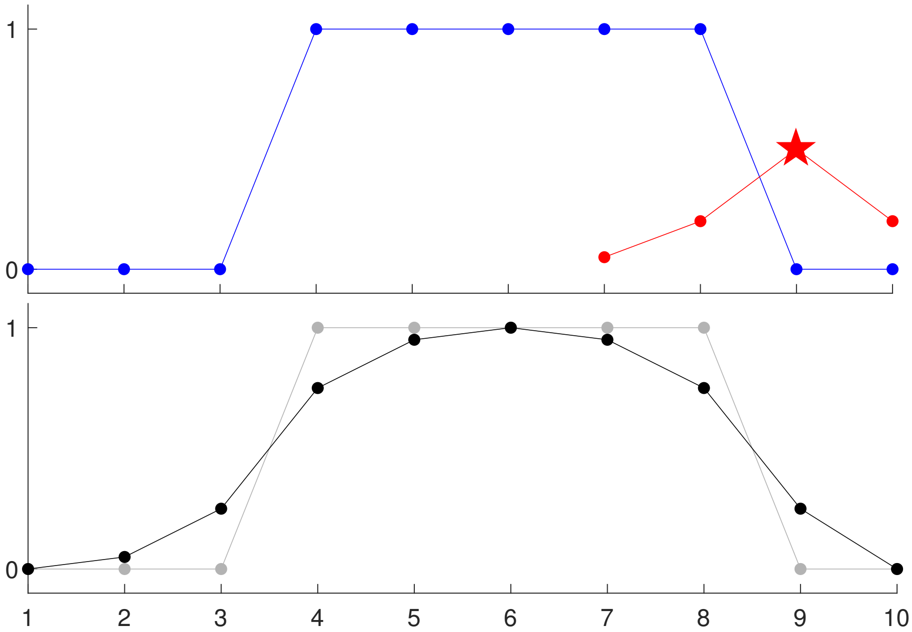
Konvoluutio, sijainti 7



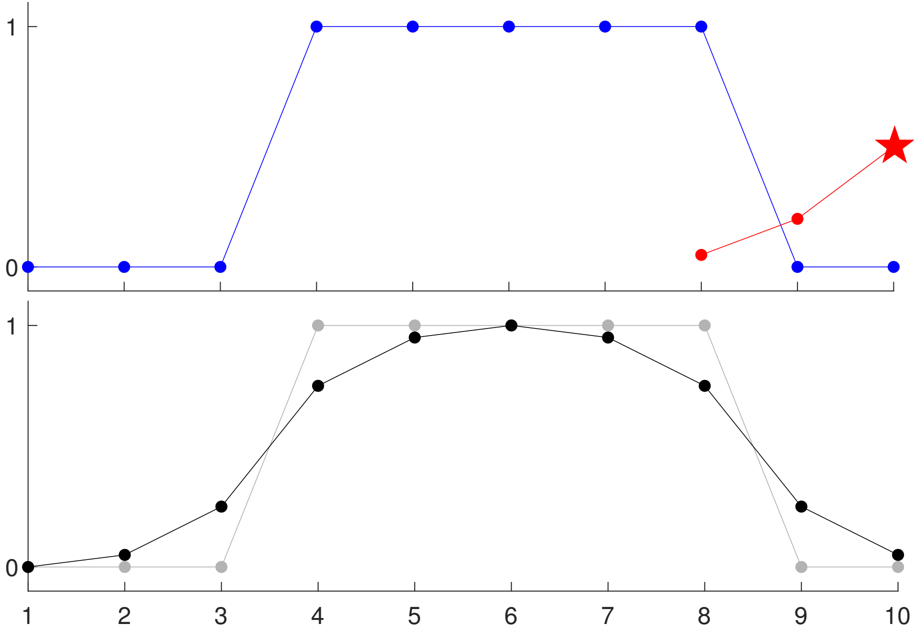
Konvoluutio, sijainti 8



Konvoluutio, sijainti 9



Konvoluutio, sijainti 10



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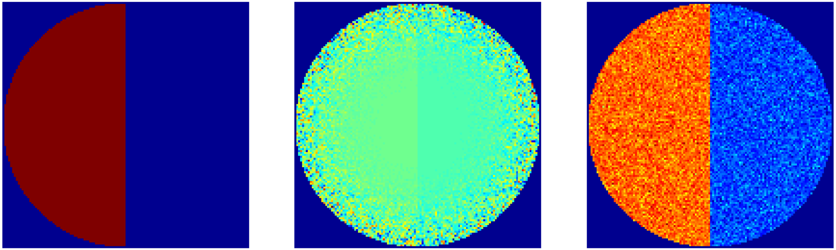
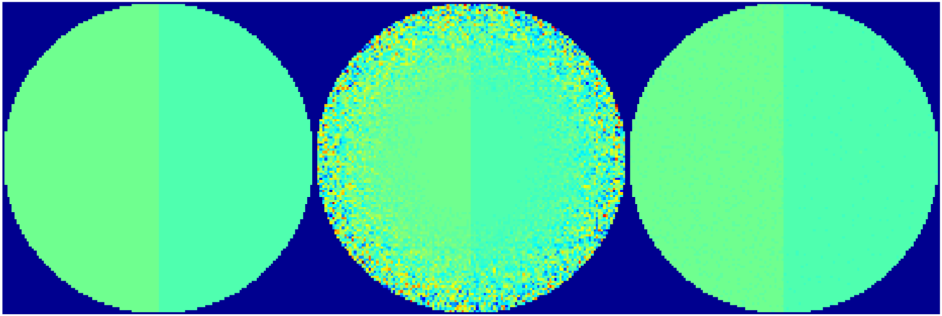
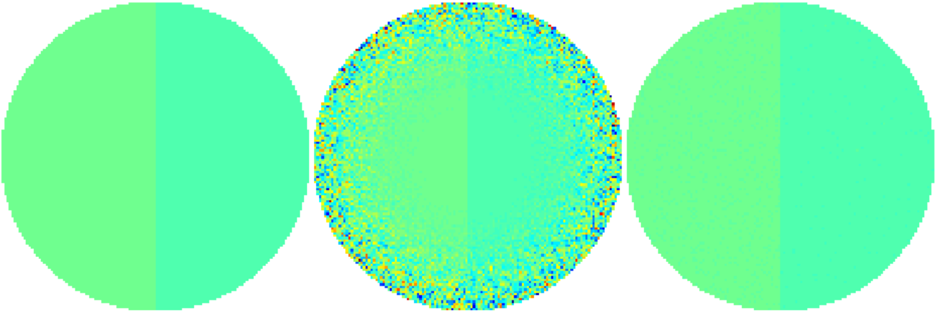
Consider these three images: true image, bad approximation and better approximation



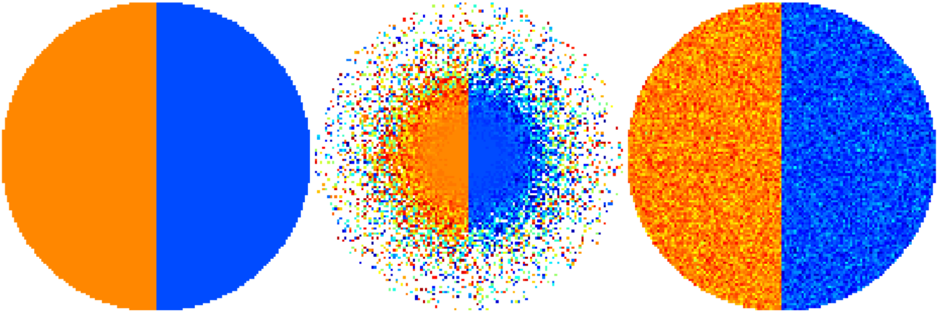
Let us show the images on the same colormap; then the same color corresponds to the same value



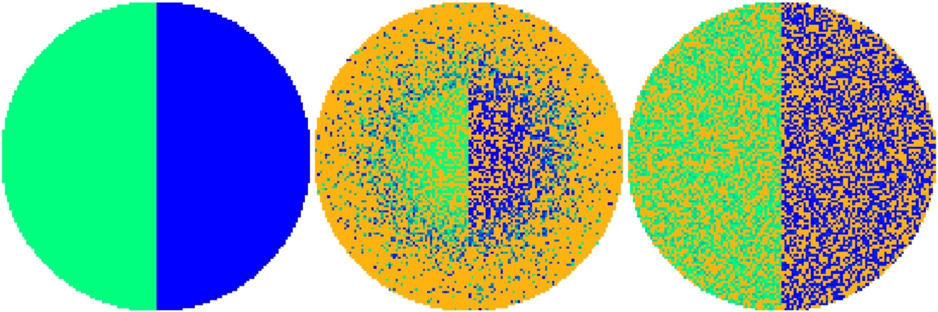
Before addressing the color-value issue, let us replace the background color by white



Now we let the true image determine a nice colormap, and out-of-range values are white



We can have a different out-of-range color to avoid blending the middle image to background



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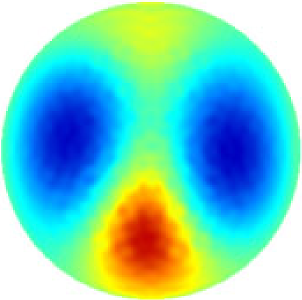
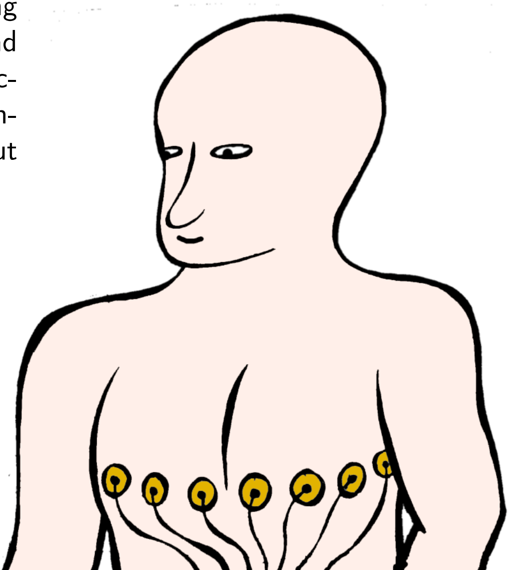
This talk concentrates on applications of EIT to chest imaging

Medical applications: monitoring cardiac activity, lung function, and pulmonary perfusion. Also, electrocardiography (ECG) can be enhanced using knowledge about conductivity distribution.





EIT can perhaps be used for imaging changes in vocal folds due to dehydration

2015 Colorado State Univ.

The mathematical model of EIT is the inverse conductivity problem introduced by Calderón

Let $\Omega \subset \mathbb{R}^2$ be the unit disc and let conductivity $\sigma : \Omega \to \mathbb{R}$ satisfy

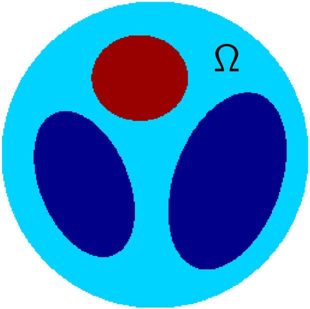
$$0 < M^{-1} \leq \sigma(z) \leq M.$$

Applying voltage f at the boundary $\partial\Omega$ leads to the elliptic PDE

$$\begin{cases} \nabla \cdot \sigma \nabla u &= 0 \text{ in } \Omega, \\ u|_{\partial\Omega} &= f. \end{cases}$$

Boundary measurements are modelled by the Dirichlet-to-Neumann map

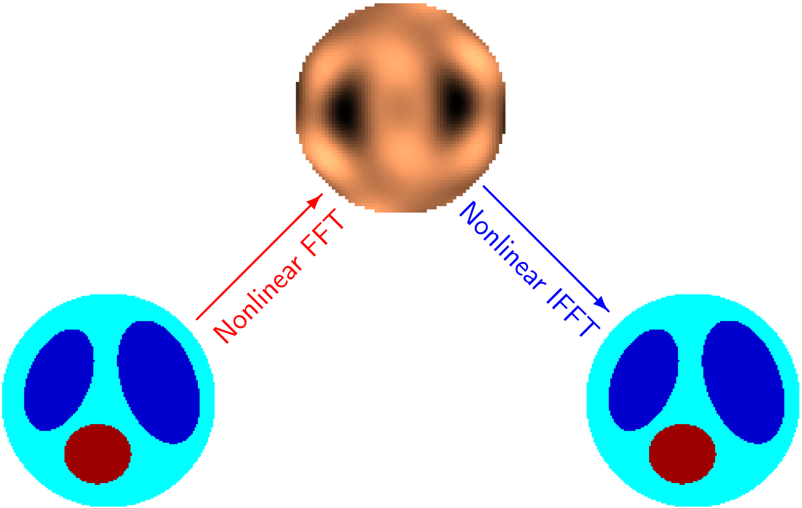
$$\Lambda_\sigma : f \mapsto \sigma \frac{\partial u}{\partial \vec{n}}|_{\partial\Omega}.$$



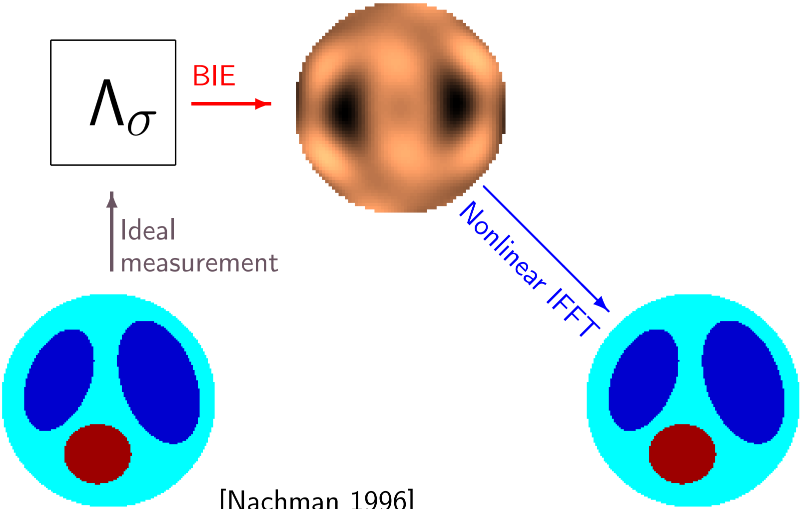
Calderón's problem is to recover σ from the knowledge of Λ_σ. It is a nonlinear and ill-posed inverse problem.

Infinite-precision data:	Practical data:
Solve boundary integral equation $\psi(\,\cdot\,,k)\vert_{\partial\Omega} = e^{ikz} - \mathcal{S}_k(\Lambda_\sigma - \Lambda_1)\psi$ for every complex number $k \in \mathbb{C} \setminus 0$.	Solve boundary integral equation $\psi^\delta(\,\cdot\,,k)\vert_{\partial\Omega} = e^{ikz} - \mathcal{S}_k(\Lambda_\sigma^\delta - \Lambda_1)\psi^\delta$ for all $0 < \vert k\vert < R = -\frac{1}{10}\log\delta$.
Evaluate the scattering transform: $\mathbf{t}(k) = \int_{\partial\Omega} e^{i\bar{k}\bar{z}}(\Lambda_\sigma - \Lambda_1)\psi(\cdot,k)\,ds.$	For $\vert k\vert \geq R$ set $\mathbf{t}_R^\delta(k) = 0$. For $\vert k\vert < R$ $\mathbf{t}_R^\delta(k) = \int_{\partial\Omega} e^{i\bar{k}\bar{z}}(\Lambda_\sigma^\delta - \Lambda_1)\psi^\delta(\cdot,k)\,ds.$
Fix $z \in \Omega$. Solve D-bar equation $\frac{\partial}{\partial\bar{k}}\mu(z,k) = \frac{\mathbf{t}(k)}{4\pi\bar{k}}e^{-i(kz+\bar{k}\bar{z})}\overline{\mu(z,k)}$ with $\mu(z,\,\cdot\,) - 1 \in L^r \cap L^\infty(\mathbb{C})$.	Fix $z \in \Omega$. Solve D-bar equation $\frac{\partial}{\partial\bar{k}}\mu_R^\delta(z,k) = \frac{\mathbf{t}_R^\delta(k)}{4\pi\bar{k}}e^{-i(kz+\bar{k}\bar{z})}\overline{\mu_R^\delta(z,k)}$ with $\mu_R^\delta(z,\,\cdot\,) - 1 \in L^r \cap L^\infty(\mathbb{C})$.
Reconstruct: $\sigma(z) = (\mu(z,0))^2$.	Set $\Gamma_{1/R(\delta)}(\Lambda_\sigma^\delta) := (\mu_R^\delta(z,0))^2$.

There exists a nonlinear Fourier transform adapted to electrical impedance tomography

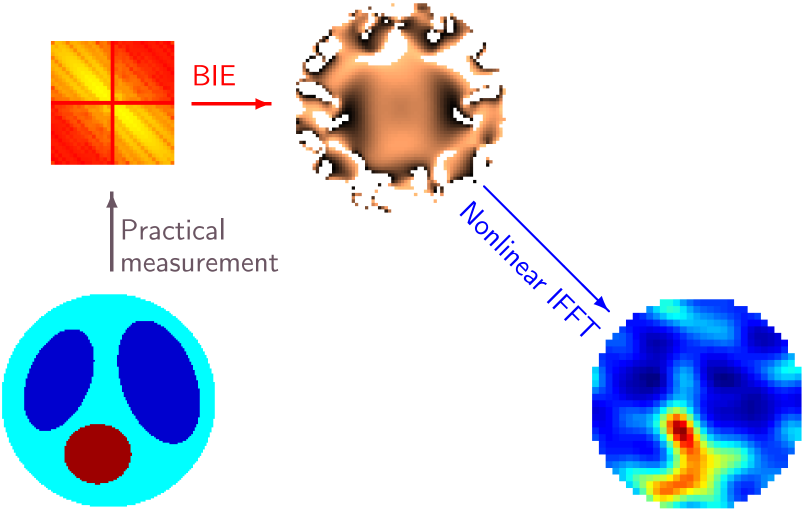


The nonlinear Fourier transform can be recovered from infinite-precision EIT measurements

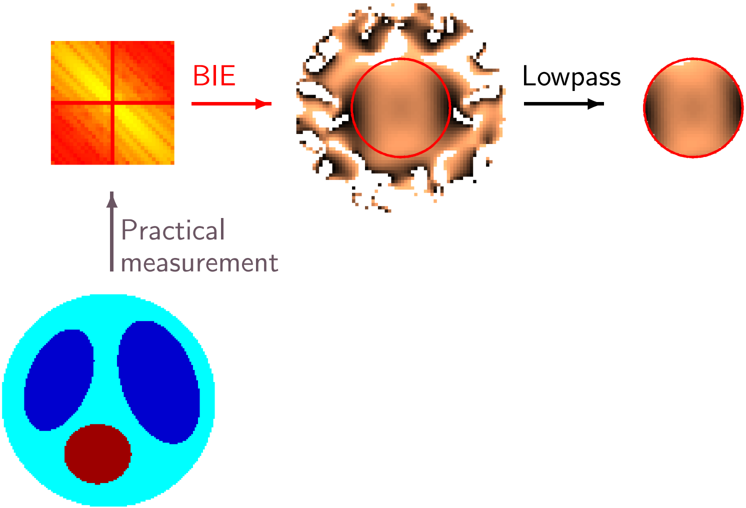


[Nachman 1996]

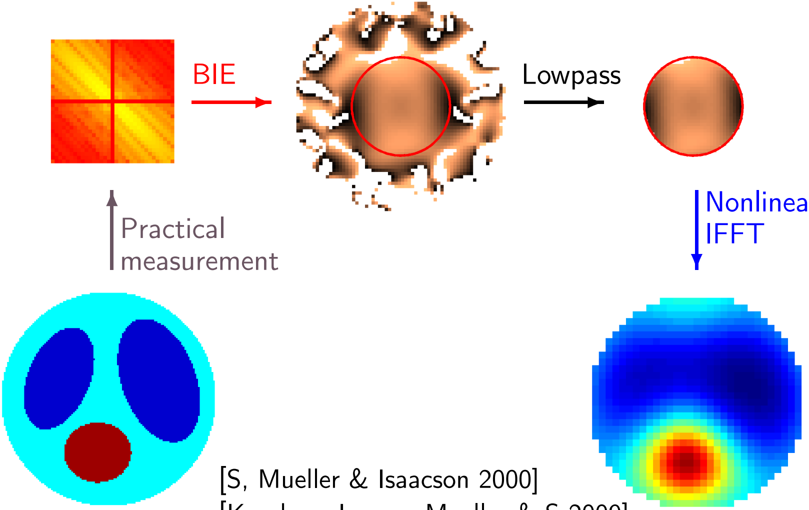
Measurement noise prevents the recovery of the nonlinear Fourier transform at high frequencies



We truncate away the bad part in the transform; this is a nonlinear low-pass filter



There is currently only one regularized method for reconstructing the full conductivity distribution



[S, Mueller & Isaacson 2000]
[Knudsen, Lassas, Mueller & S 2009]

Useful links

Blog post: Plotting a function of one variable

Blog post: Displaying Image Data for Comparison

Visualisointiin voi käyttää mitä tahansa softaa,

kuha on hallinnassa